Oscillations in Emerging Active Regions on the Sun

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Introduction

What are Active Regions?

An active region (AR) is an area on the sun with a prominent bipolar magnetic field. This dense magnetic bipolarity is what makes an active region different from the surrounding "quiet" sun. The plasma medium of the sun follows the magnetic field lines of an active region causing characteristic magnetic flux "loops" to emerge. If an active region is on the edge of the solar disk (the "limb"), these coronal loops are traced out against the sky. The appearance of an active region, however, depends on both the wavelength is it viewed in as well as the angle at which it is observed. *Figure 1* shows an AR in extreme ultraviolet, in a magnetogram, and at the limb. The sun is a dynamic system and has many processes in play making any one active region temporary and their lifetime depends mostly on their size (Canfield, R. 2000).

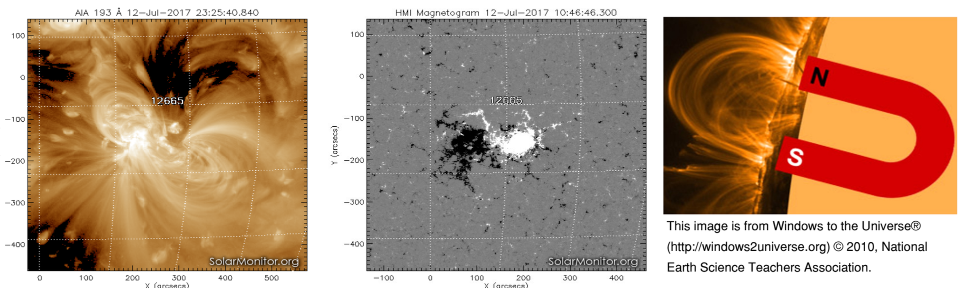


Figure 1. Images displaying active regions.

Active regions can produce solar flares and coronal mass ejections (CMEs). A CME is the mass discharge of magnetized plasma from the surface of the sun. CMEs are of particular importance to space weather forecasters and scientists in general because they are well known to cause strong geomagnetic storms that potentially have serious impacts on our ionosphere, atmosphere, and on the ground.

Space Weather Forecasting

Space weather forecasters in the Community Coordinated Modeling Center (CCMC) at NASA Goddard are able to use tools like the integrated Space Weather Analysis system (iSWA) to study and forecast space weather. There are over 300 different signets that can be used to display data from different sources. *Figure 2* shows a few examples that are useful to space weather forecasters when looking at active regions. These tools include images at different wavelengths and line-of-sight magnetic field of the sun (black and white indicating polarities).

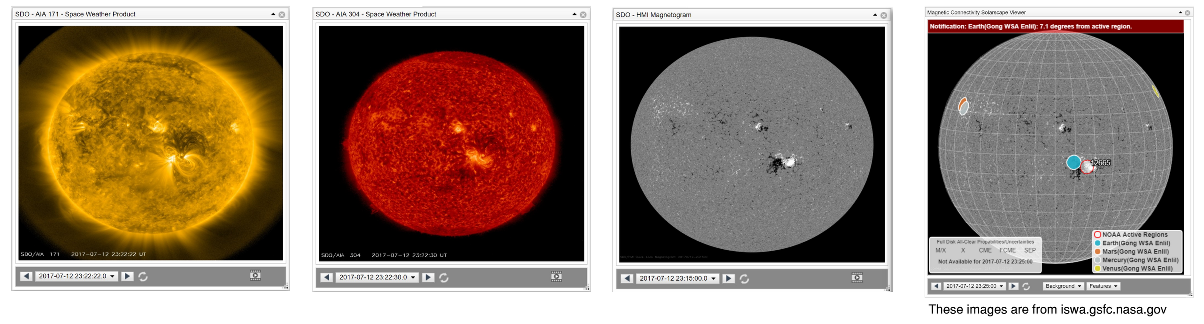


Figure 2: (L to R) 171 Å, 304 Å, magnetogram, and magnetogram with NOAA AR 2665.

Background

ARs on the sun are directly related to space weather phenomena like flares and coronal mass ejections. Predicting when and where ARs will emerge at the surface of the sun would therefore strengthen our space weather forecasting abilities. Solar Dynamics Observatory (SDO) provides images of the magnetic field (magnetograms) and Doppler velocity (dopplergrams) in the photosphere of the sun. Oscillations present in the Dopplergrams allows the emergence of ARs to be studied.

It is well known that **global oscillations travel through the solar interior and are modified in the presence of a magnetic field**. This means, the oscillation patterns in the quiet, non-active sun are different from oscillation patterns in and around ARs.

With the motivation of predicting ARs, the hours prior to AR emergence are of great importance. Magnetogram data provide a time when the magnetic field of the active region reaches the solar surface.

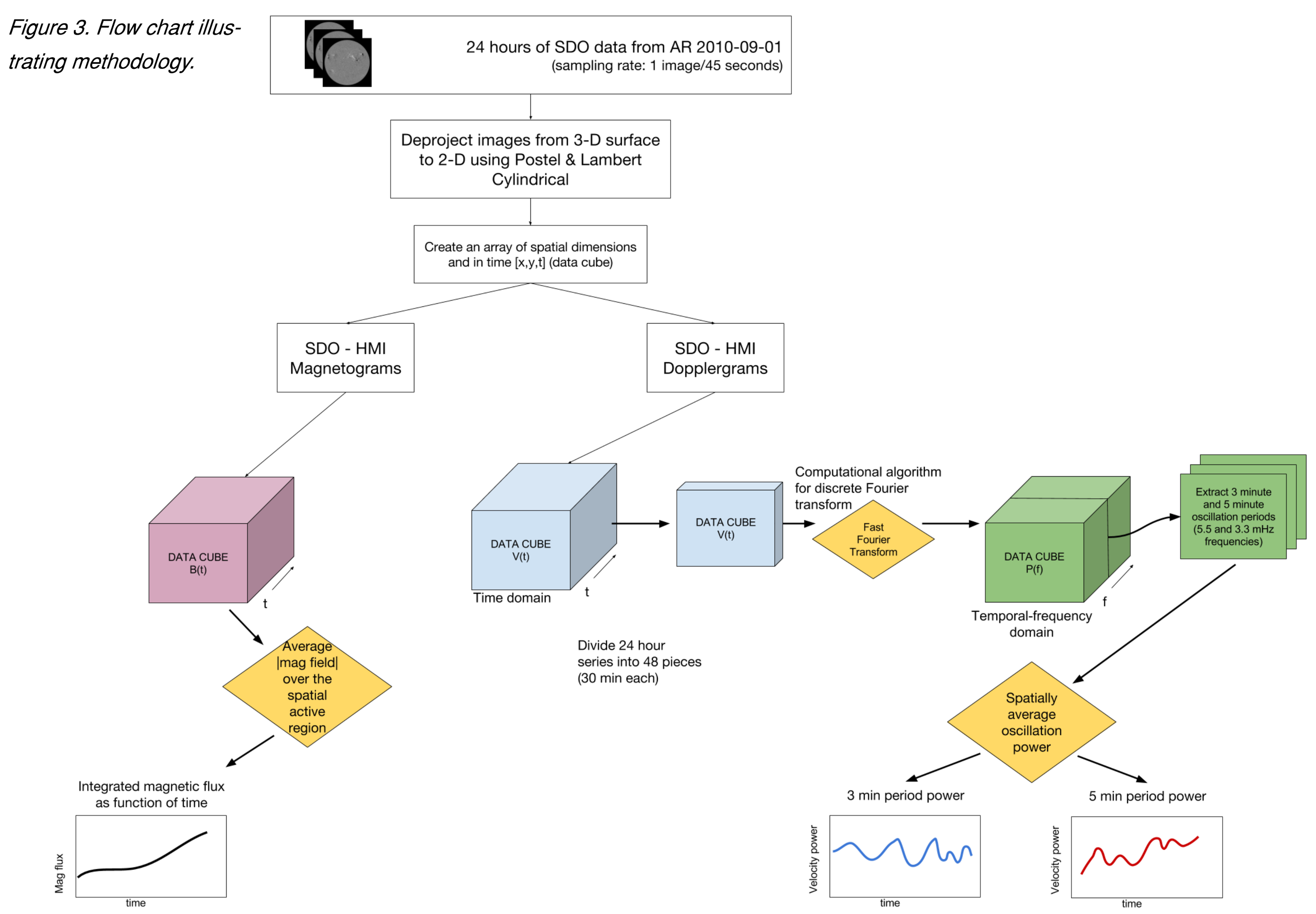
- Compute Fast Fourier Transforms (FFTs) of SDO Dopplergrams to calculate oscillation patterns
- Compare the calculated oscillation period and oscillation powers to AR emergence time in the magnetograms.
- Qualitatively analyze if there is any time delay between a change in oscillation power and the time of the AR emergence.

Helioseismologists have known oscillations on the sun are predominantly of 5-minute and 3-minute periodicities. The prevailing period of the oscillations on the quiet sun are 5-minutes. In and around ARs it has been observed that the oscillations are of 3-minute periods.

Method

SDO HMI data of an emerging active region from 2010-09-01T12:00Z to 2010-09-02T12:00Z (24 hours) was taken and deprojected using two deprojection schemes, Lambert Cylindrical (LC) and Postel. *Figure* 3 (below) shows how the data was manipulated further.

Figure 3. Flow chart illustrating methodology.



Results

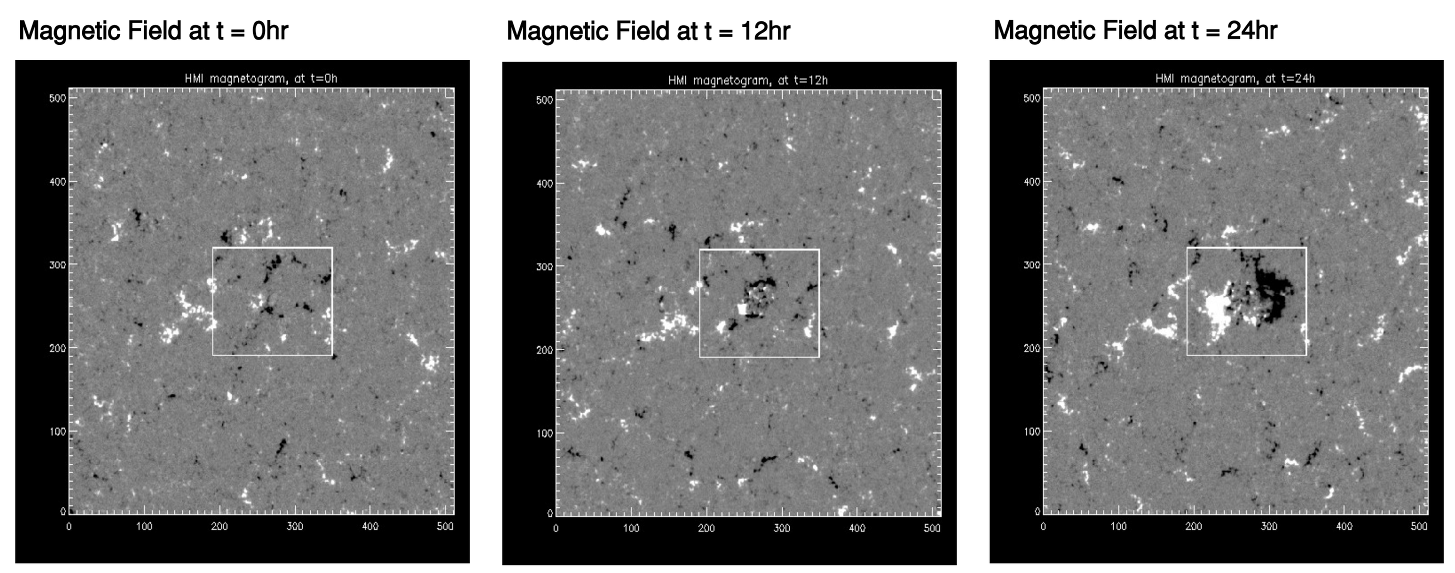


Figure 4: Evolving magnetic flux and emerging active region in the white box over 24 hours.

Doppler Velocity Oscillation Power Maps

(from the last 30 min of the time series)

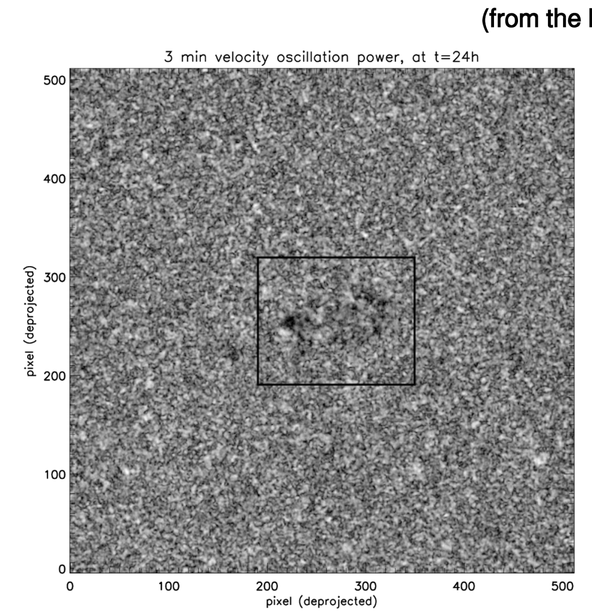


Figure 5. Three minute oscillation power map

The traced boxes indicates the consistent spatial region used for integration.

Pixel dimension:

x=190:350

y=190:320

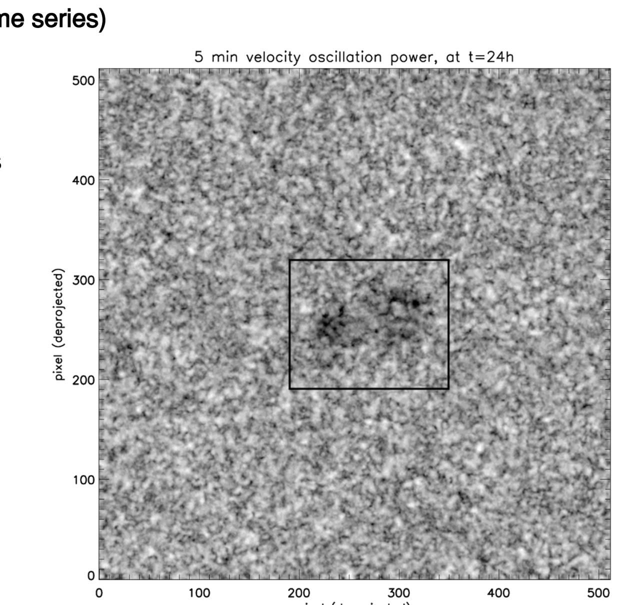


Figure 6. Five minute oscillation power map.

Results Cont.

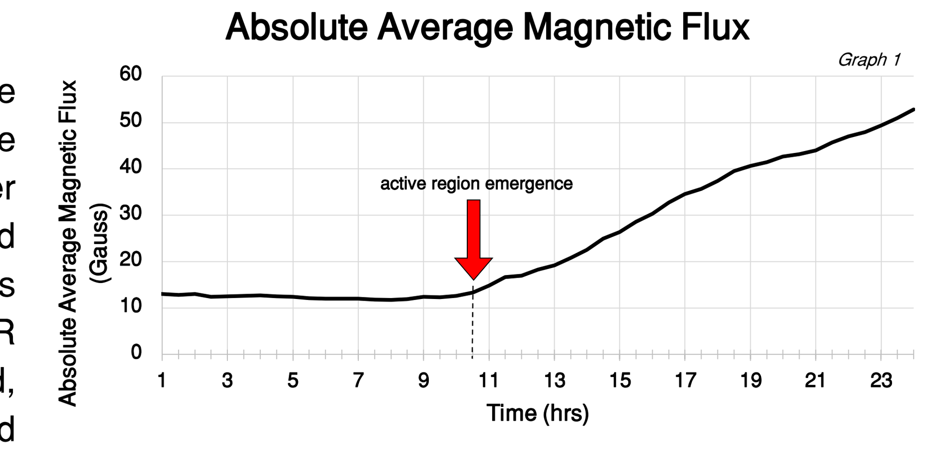
Figure 4 shows the evolution of the magnetic field of the AR. *Graph 1* is the integral of the absolute magnetic flux over the 24-hour period inside the boxed region. The increase in magnetic flux is an indication of the start of the AR emergence. For the active region studied, this occurs around the 11th hour (see red arrow and dashed line in all graphs).

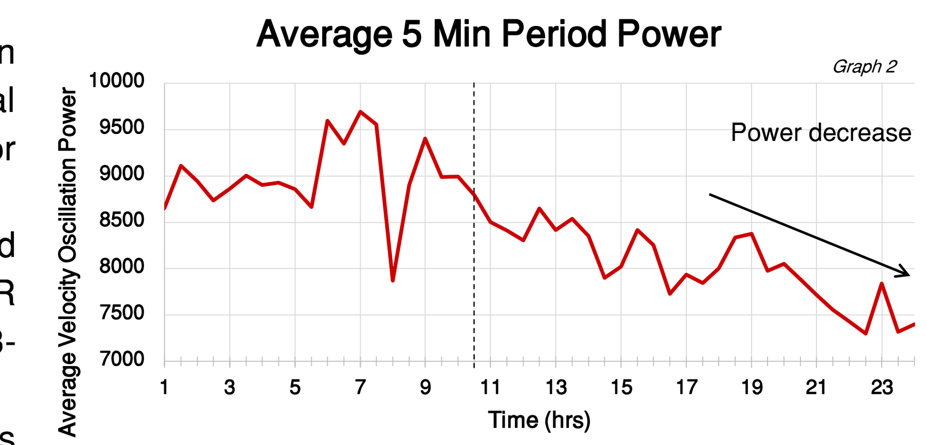
The Postel and LC deprojection schemes yield essentially identical results, and for clarity only the results for Postel deprojection are displayed.

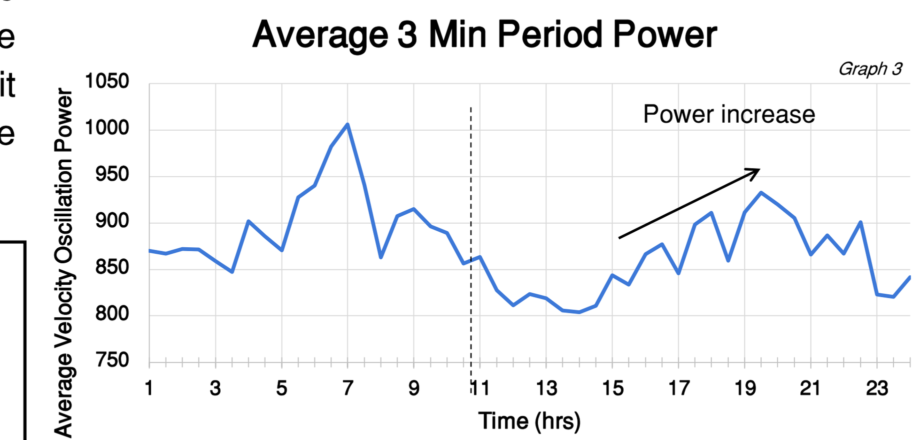
Graph 2 shows the 5-minute period oscillation power averaged over the AR and *Graph 3* shows the same for 3-minute period oscillations.

The dashed line shown in the graphs give the time when the AR reaches the photosphere of the sun and we can use it to compare the oscillation powers with the magnetic field emergence.

Summary:
- Magnetic flux increase can be attributed to AR emergence
- 5 min period power decreases
- 3 min period power decreases then increases







Discussion

Comparing the flux emergence time with the change of the 5-minute and 3-minute oscillations power, it can be seen at the time the AR starts to emerge, the oscillation power decreases. It is a well-known fact that magnetic fields on the sun, above a certain field strength, suppress the plasma dynamics including solar oscillations. The 5-minute oscillation power decreases for a whole period of time (until the end of our observing time). The 3-minute power oscillations first start to decrease at about hour 14, then it starts to increase again. The increased 3-minute oscillation power around ARs have been observed before (e.g. Muglach et. al. 2005, Hanson, et al. 2015) and are called **oscillation power halos**. They are most likely the cause of the power increase in *Graph 3*, although it is spatially integrated.

Both oscillation power graphs show an increase of power a few hours prior to the emergence time. This effect is unexplained and has to be confirmed by additional observations. We are planning to analyze several other ARs to confirm these results and to investigate their possible use for the forecasting of AR emergence.

References/Acknowledgements

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